EPA

U.S. EPA
OSWER #9285.7-37
March 2003

TRW RECOMMENDATIONS FOR PERFORMING HUMAN HEALTH RISK ANALYSIS ON SMALL ARMS SHOOTING RANGES

Office of Solid Waste and Emergency Response
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Washington, DC 20460

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U.S. ENVIRONMENTAL PROTECTION AGENCY
TECHNICAL REVIEW WORKGROUP FOR LEAD

The Technical Review Workgroup for Lead (TRW) is an interoffice workgroup convened by the U.S. EPA Office of Solid Waste and Emergency Response/Office of Emergency and Remedial Response (OSWER/OERR).

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Executive Summary

Past management practices at small arms outdoor shooting ranges (subsequently referred to as 'ranges') allowed the spent ammunition to accumulate on site. Many range operators now recognize the risk posed to humans and the environment by spent lead ammunition and have implemented programs to manage and recycle lead shot and bullets. In accordance with its mission to provide scientifically sound and consistent guidance on lead risk assessment, the TRW has prepared this document to provide guidance and recommendations for performing risk assessment on land currently or formerly used as ranges. This document supplements Region 2's Best Management Practices for Lead at Outdoor Shooting Ranges (U.S. EPA, 2001a), which serves as national guidance on the management of lead at ranges to minimize the environmental impact of spent lead ammunition (U.S. EPA, 2001b).

As used in this document, the term 'small arms' includes rifles, handguns (pistols), shotguns, submachine guns, and machine guns (NRA, 1999, p. I-8). Ranges can be divided into high velocity shooting ranges, where target shooting with pistols and rifles occurs, and low velocity shooting ranges where shotguns are used (i.e., skeet, trap, and sporting clay ranges). Lead bullets and fragments at pistol and rifle ranges are typically contained in a relatively small, well-defined area, or volume, of sand and/or soil. The shotfall zones at skeet and trap ranges may cover 10–50 acres or more, depending upon the layout of the range.

This document contains brief discussions of the regulatory background for outdoor shooting ranges and the toxicology of lead on humans, an operational and physical description of the different types of outdoor shooting ranges, and the fate of spent lead ammunition in the environment and its bioavailability. This document provides recommendations on how the Integrated Exposure Uptake Biokinetic model and the Adult Lead model can be used to predict the risk to human health from spent lead ammunition on small arms shooting ranges.

Background and Purpose

There are approximately 9,000 outdoor small arms shooting ranges (subsequently referred to as 'ranges') in the United States, excluding those located on military sites (U.S. EPA, 2001a). Millions of pounds of lead are discharged annually at these ranges (U.S. EPA, 2001a). In the past, the common practice at ranges was to allow the spent ammunition to accumulate on site. Many range operators now recognize the risk posed to humans and the environment by the lead in spent ammunition and have implemented programs to manage and recycle lead shot and bullets.

Given the large number of ranges in the United States and their potential risk to humans, the Technical Review Workgroup for Lead (TRW) has prepared this document to assist Regional and State risk assessors and project managers in performing risk assessments at range sites. The proper management of lead at shooting ranges is addressed in an EPA Region 2 document entitled "Best Management Practices for Lead at Outdoor Shooting Ranges" (U.S. EPA, 2001a). This white paper contains the TRW's recommendations on how to collect data that will be used to provide site specific information when using the Integrated Exposure Uptake Biokinetic (IEUBK) Model and the Adult Lead Model (ALM) (U.S. EPA, 2002c). The focus of this document is on formerly used ranges, although exposure to active ranges may occur and is also discussed.

Introduction

As used in this document, the term 'small arms' includes rifles, handguns (pistols), shotguns, submachine guns, and machine guns (NRA, 1999, p. I-8). Spent ammunition on ranges is not regulated as solid/hazardous waste unless it is discarded (abandoned) and left to accumulate for a long period of time (U.S. EPA, 2001a). Furthermore, it is not regulated if the spent ammunition is recovered or reclaimed on a regular basis (U.S. EPA, 2001a). However, if the range poses an imminent or substantial danger to health or the environment it can be addressed through Resource Conservation and Recovery Act (RCRA) (U.S. EPA, 2001a).

The intake of lead has a wide variety of effects on humans. Adults and children exposed to lead are susceptible to neurotoxic effects (ATSDR, 1999). Lead may also increase blood pressure and cause anemia; high levels of exposure to lead may damage the brain and kidneys and even cause death (ATSDR, 1999; U.S. EPA, 2002b). High levels of exposure may cause miscarriages, retard fetal development, and damage the organs responsible for sperm production (ATSDR, 1999; U.S. EPA, 2002b). Other effects of lead exposure include irritability, poor muscle coordination, muscle and joint pain, memory and concentration problems, digestive problems, and hearing and vision impairment (U.S. EPA, 2001a, 2002b). In children, lead exposure can cause behavioral and learning problems, hearing problems, impairment of vision and motor skills, hyperactivity, and developmental delays (ATSDR, 1999; U.S. EPA, 2001a, 2002b). Blood lead concentrations of 10 µg/dL or less have been associated with adverse health effects in children (U.S. EPA, 1986a; CDC, 1991). It is EPA policy to limit exposure to lead such that the probability of a typical (or hypothetical) child, or group of similarly exposed children, having or exceeding the 10 µg/dL blood lead concentration is less than 5% (U.S. EPA, 1994a).

Other chemicals of potential concern at shooting ranges include arsenic and antimony (components of ammunition), nickel (coating on some lead shot), copper, zinc, strontium, and magnesium (present in tracer munitions that are used in machine guns), and polycyclic aromatic hydrocarbons (present in petroleum 'pitch' found in clay targets used at skeet and trap ranges and in 'wadding' from shotgun shells) (Jorgensen and Willems, 1987; EEA, 1992; EA, 1995; Peddicord and LaKind, 2000). Lead shot contains primarily lead (97%), antimony (2%), arsenic (0.5%), and sometimes nickel (0.5%) (Jorgensen and Willems, 1987; Lin et al., 1995). The crust material surrounding lead shot contains between 0.5 and 2.0% antimony, 0.15% nickel, and trace amounts of arsenic (Jorgensen and Willems, 1987). Lead bullets are composed of 90–99% lead, 1–10.5% antimony, and 0.1% copper (EA, 1996). Baer et al. (1995) determined that clay targets ('pigeons') contain approximately 2/3 dolomitic sandstone and 1/3 pitch; painted targets also contain approximately 1% fluorescent paint.

Due to a ban on the use of lead shot for waterfowl hunting and in waterfowl production areas by the U.S. Fish and Wildlife Service (U.S. FWS, 1999, 2001), other less toxic materials have been introduced, such as bismuth, steel, tungsten/iron, and tungsten polymers (a list is provided in EPA, 2001a, Appendix B). However, due to the higher cost of shot that is manufactured with the less toxic material, lead shot continues to be the most commonly used material on skeet and trap shooting ranges (U.S. EPA, 2001b).

Types of Shooting Ranges

Ranges can be divided into high velocity shooting ranges, where target shooting with pistols and rifles occurs, and low velocity shooting ranges where shotguns are used (i.e., skeet, trap, and sporting clay ranges). Appendix A contains a list of on-line sources of additional information for small arms outdoor shooting ranges.

High Velocity (Pistol and Rifle) Shooting Ranges

High velocity ranges consist of a firing line, targets, backstop (to contain bullets and fragments), side berms (to contain ricochets), and ground and overhead baffles (to contain 'short' and 'long' shots, respectively) (Vargas, 1996). Not all ranges, particularly older ranges, will include all these components. Typical lengths for ranges vary between 25 yards and 200 meters (642 yards) (Vargas, 1996); widths depend on the number of firing stations.

The backstop is required to contain the bullets and bullet fragments. Backstops traditionally consist of earthen berms, typically between 15 and 25 feet high. More recently, earthen berms have been replaced with sand traps, steel traps, and rubber traps (U.S. EPA, 2001a). Other innovations have been developed for backstops, such as Shock Absorbing Concrete (SACON) that has been used on some Department of Defense (DOD) ranges since the 1980s (U.S. EPA, 2001a). The purpose of the newer types of backstops/bullet containment devices is to facilitate the collection of bullets and bullet fragments, which substantially reduces the amount of contaminated media generated by the range.

Low Velocity (Shotgun) Shooting Ranges

Shotguns are used to shoot clay targets ('pigeons' or 'birds') on skeet, trap, and sporting clay ranges. In many cases, skeet and trap shooting takes place in one range. A typical trap range consists of five-shooting positions and one structure, the 'traphouse', from which the targets are thrown by a machine called a 'trap'. The angle at which the targets are thrown varies within an arc of 45 degrees (in a horizontal plane). The shooting positions are located 16 yards from the traphouse (Capital Trap Club, 2001a). At skeet ranges, targets are released from two structures, the 'high house' and the 'low house.' There are eight-shooting positions arranged along an arc between the two houses. At the top of the arc, the shooter is approximately 30 yards from the line that connects the two houses (Capital Trap Club, 2001b). The actual layout of skeet and trap ranges varies widely between sites (e.g., EA, 1995; E&E, 1997; Murray et al., 1997).

The size and shape of the shotfall zone is a function of the layout of the site, and ranges from rectangular for sites with multiple ranges located next to each other (e.g., E&E, 1997), to semi-circular for sites with one range (e.g., EA, 1995). The outfall zone from trap shooting will tend to be less than for skeet shooting due to the angle at which shooting occurs. In skeet shooting, the targets are thrown overhead and the shooting angle is approximately 45 degrees from the horizontal. Targets are released much closer to the ground in trap shooting; the shooting angle is approximately horizontal. Another factor that affects the distance the shot will travel is the size of the shot used. When the shooting angle is approximately horizontal, the maximum distance shot will travel varies from 198 yards for No. 8 shot to 330 yards for No. 2 shot (Baldwin, 1994). Number 6 shot will cover an area between 300 and 700 feet from the shooting position when the shooting angle is level; if released from an angle of 40 degrees from the horizontal, the shot will drop between 400 and 900 feet from the shooting position (Baldwin, 1994).

FATE OF LEAD AMMUNITION IN THE ENVIRONMENT AND BIOAVAILABILITY

Lead ammunition oxidizes in the environment, forming a crust around the shot; this crust contains lead carbonates and sulfates (Jorgensen and Willems, 1987; Manninen and Tanskanen, 1993; Lin et al., 1995; EA, 1996; Murray et al., 1997). The predominate lead carbonates that have been found in the crust material include hydrocerussite ($Pb_3(CO_3)_2(OH)_2$) and cerussite ($PbCO_3$); the predominate lead sulfate compound is anglesite ($PbSO_4$). The rate of oxidation depends upon several environmental factors including: oxidation/reduction potential, ionic strength, pH, oxygen content of the soil and the presence of compounds (e.g., phosphate) that may inhibit oxidation (Jorgensen and Willems, 1987; EA, 1996). At some point, the presence of the crust material appears to inhibit the further weathering of the ammunition (Jorgensen and Willems, 1987). While metallic lead is insoluble under typical environmental conditions, lead is released to the environment through the dissolution of the lead compounds found in the crust material (Jorgensen and Willems, 1987; Manninen and Tanskanen, 1993; Lin et al., 1995; EA, 1996; Murray et al., 1997). The solubility of the lead compounds is affected by pH, eH, the presence of carbonate, sulfate, sulfide, phosphate and chloride, and the organic matter content of the soil (Jorgensen and Willems, 1987; Manninen and Tanskanen, 1993; Lin et al., 1995; EA, 1996; Murray, 1997).

Site-specific environmental factors that affect weathering rates of lead on shooting ranges include the amount of precipitation, pH of rain water, slope of the ground surface, amount of organic material present on the ground surface (e.g., leaves, peat) and soil type (U.S. EPA, 2001a). In general, weathering of lead ammunition will increase with increasing precipitation amounts, increase with decreasing pH, increase with increasing chloride concentration, decrease with increasing ground slope (due to decrease in contact time between precipitation and ammunition) and increase with increasing organic matter cover (U.S. EPA, 2001a). Disturbance of the soil (e.g., soil cultivation of agricultural fields) may increase the decomposition of lead ammunition (Jorgensen and Willems, 1987). Bundy et al. (1996) found high corrosion rates were negatively correlated with corrosion potential and soil resistance, two characteristics of the soil environment that can be measured in the field.

The weathering rate of small arms ammunition may be affected by the presence of a copper 'jacket' or metal casing that surrounds the lead core of some ammunition (Major, 2003). The contact between the different types of metals may create a galvanic couple that increases the rate of corrosion of the ammunition if the moisture content of the surrounding soil is sufficiently high. However, on some sites, jacketed bullets do not appear to corrode at a faster rate than unjacketed bullets (Hall, 2002). Jacketed bullets are common on small arms ranges that are located on DOD sites because the military is required to use jacketed bullets; jacketed bullets are much less common on non-military ranges (Hall, 2002). Bullet jackets typically contain (by weight) 89–95% copper, 0.03–0.05 % lead, 0.05% iron, and 5–10 % zinc (Battelle, 1997).

The bioavailability of lead compounds varies greatly from lead sulfates, which have relatively low bioavailability (<25% bioavailable), to lead carbonates (>75% bioavailable) (Henningsen et al., 1998). The overall bioavailability of lead at shooting ranges depends upon the relative amounts of lead carbonates and lead sulfates that are present in the soil. Equilibrium diagrams (i.e., eH-pH diagrams) predict lead sulfates to be the dominant form of lead at pHs <5.3, carbonates to be the dominant form at pHs between 5.3 and 8.5, and lead hydroxides to dominate at pHs >8.5 (EA, 1996). The speciation found at a particular site will also vary depending upon the amount of carbonate and sulfate present in the soil (EA, 1996).

SITE CHARACTERIZATION AND RISK ASSESSMENT

An important difference between high velocity ranges and low velocity ranges, with respect to risk assessment, is the size of the areas impacted by each type of range. Lead bullets and fragments at pistol and rifle ranges are typically contained in a relatively small, well-defined area, or volume, of sand and/or soil. Very little contamination may be found at a well-designed range equipped with bullet traps, although some traps and targets (e.g., steel targets) may generate lead dust and particulates that can be transported by air and water and contaminate the surrounding area.

Due to the relatively small size of typical pistol and rifle ranges, the risks posed to human and ecological receptors are typically low. Exceptions to this would include former ranges that are planned for development, or are currently used for activities that could result in exposure to human and ecological receptors. Risks to human and ecological receptors from exposure to lead and other contaminants at skeet and trap ranges may be moderate to severe, due to the size of the shot outfall area. In some cases, the outfall areas are located within or near wetlands and surface water, which tends to increase the risks to ecological receptors, particularly waterfowl (EA, 1995; E&E, 1997; U.S. EPA, 2001a).

The difference between the types of exposures at high velocity and low velocity ranges also warrant consideration in the exposure assessment. These differences are due to the nature of the lead contamination in soil. At high velocity ranges, in addition to whole bullets and fragments, small particles of lead will be present due to the partial disintegration of the bullets upon impact with the targets and soil and rock particles in the berms (EA, 1996). Less disintegration of the bullets can be expected where fully jacketed and partially jacketed bullets are used (e.g., military ranges). At low velocity ranges, the lead shot will tend to be less fragmented due to the lower velocities. Although lead shot does break down in the environment, complete decomposition of the lead is a slow process that may take 30–300 years, depending upon site conditions (Jorgensen and Willems, 1987; EA, 1996).

Exposure Scenarios and Pathways

Land use adjacent to and near shooting ranges should be considered when developing current and future exposure scenarios for a site. Under the current land use scenario, the potentially exposed human populations of particular concern at an operating range are residents of adjacent residential properties, residents and farm workers on adjacent agricultural properties, and workers who are employed on adjacent commercial properties. Other receptors include trespassers who use the site for recreational purposes such as fishing, hunting, and hiking (Peddicord and LaKind, 2000; U.S. EPA, 2001a), as well as other recreational users when the range is located on or within an area that is used for recreational activities other than target shooting (e.g., multi-use parks). Under future land use scenarios, the potentially exposed population depends upon the intended or actual land use, which may include residential, agricultural, commercial, or industrial uses.

The potentially exposed populations under both future and current land use scenarios that should be considered are:

- Residential land use:
  - children under the age of 7 years old
  - adults
- Agricultural land use (farm family or subsistence farm family):
  - children under the age of 7 years old
  - adults
  - farm workers
- Commercial and industrial land use:
  - adults
  - trespassers
  - maintenance staff/construction workers who may be exposed during invasive work (e.g., excavating trenches to install/repair utilities)

The main pathway for human exposure to lead at shooting ranges is through incidental ingestion of contaminated soil (Peddicord and LaKind, 2000; U.S. EPA, 2001a). The ingestion of site-raised meat (beef, pork, chicken) and fruits and vegetables contaminated with lead dust may also pose a risk for local residents and especially for local farm families; these pathways must be evaluated in the latter scenario. Grazing farm animals may ingest and bioaccumulate large quantities of lead [Braun et al.,1997]. In addition, the inhalation of dust/soil particles may be a potential pathway depending upon site conditions, particularly during activities that involve the excavation of soil (e.g., during maintenance and construction work), or during agricultural activities (e.g., tilling, planting, and plowing) that may release clouds of dust. Hunters (and poachers) may be exposed via consumption of lead-contaminated wildlife (EA, 1995; E&E, 1997; Peddicord and LaKind, 2000; U.S. EPA, 2001a). Children who exhibit pica behavior may be at risk from exposure to formerly used shooting range sites; however, the pica child will not be considered in this document. In most cases, the primary receptor of concern will be children and farmers who are potentially exposed to formerly used ranges and adjacent contaminated areas. (The subsistence farm family ingestion rate of relevant meat or site-raised crops is assumed to comprise a large part of the diet; data is currently available in the Exposure Factors Handbook to evaluate this scenario and the EPA Default Exposure Factors Workgroup is developing default values as well.)

Ecological receptors of concern at shooting ranges include invertebrates, fish, mammals and birds, particularly waterfowl. Pathways include the incidental ingestion of soil, intentional ingestion of lead fragments as grit, and the ingestion of contaminated food items. Risk assessments at shooting ranges have predicted unacceptable levels of risk from lead for raptors, and small (e.g., mice) and large (e.g., fox and deer) terrestrial mammals (EA, 1995; Peddicord and LaKind, 2000). The highest risks from lead have been predicted for small mammals and birds that ingest lead shot incidentally while feeding, or intentionally as grit (EA, 1995; Peddicord and LaKind, 2000). The predicted adverse effects of lead on small mammals and birds, are supported by the literature, which has shown mortality may result from the ingestion of one lead pellet (e.g., Ma, 1989; Roscoe et al., 1989; Hoffman et al., 2000; Vyas et al., 2000). Additional information is available from the EPA ECOTOX database (U.S. EPA, 2002a). Consultation with an ecotoxicologist is recommended when planning an ecological risk assessment.

Soil Sampling Strategies and Recommendations

This section is divided into three subsections: 1) General Sampling Strategy, 2) Sample Collection at High Velocity Ranges, and 3) Sample Collection at Low Velocity Ranges. The overall sampling strategy and soil recommendations that are common to both types of ranges are discussed in the General Sampling Strategy subsection. Recommendations that are specific to the two types of ranges are provided in the second and third subsections.

General Sampling Strategy. Sampling may be required to support several different management strategies at a shooting range. The initial visual inspection of the site and a review of operating records may indicate that sufficient spent ammunition exists, making removal and recycling cost effective. For small ranges, particularly pistol and rifle ranges, it may be cost effective to remove or remediate contaminated material rather than conduct a risk assessment. In this case, an initial sampling maybe conducted to determine the amount and type of sampling data required to characterize the material for treatment or disposal, followed by a screening to ensure the remaining soil does not pose a potential risk. Even when recycling will not be a primary management strategy for the site, it is recommended to reclaim spent ammunition from the range prior to collection of data to support a risk assessment in order to avoid duplication of effort. The risk assessment may be conducted to determine the potential for imminent risk, evaluate the risk posed by residual levels of lead in soil, or to develop further management strategies. A first step in the risk assessment is to define the exposure area(s) for the site. Exposure areas should be small enough to reflect an area of repeated site use by a hypothetical individual. Additional exposure areas may need to be defined for agricultural activities, including crop planting, maintenance and harvesting, and grazing.

The following recommendations for sampling have been developed to produce data that are adequate for use with the IEUBK and/or ALM. Given the primary exposure pathways (i.e., incidental ingestion of soil), the objectives of the sampling effort should include producing precise estimates of the exposure point concentration (EPC) for lead in soil. Sampling designs for outdoor shooting ranges should be appropriate for estimating the mean of skewed distributions (Cochran, 1977, p.40; Chen, 1995). Data from skeet and trap ranges indicate the distribution of lead is typically positively skewed, with concentrations in sieved samples ranging from <1 to 161,000 ppm and coefficients of skewness ranging from 1.0 to 8.3 (Dragun Corp., 1992; EA, 1994, 1995; E&E, 1997; Murray et al., 1997; TTNUS, 2001). Data from rifle and pistol ranges indicate the range of lead concentration may vary from background levels to 3.9% lead (39,000 ppm), by weight (Dragun Corp., 1992; EEA, 1992).

Sampling depth should be appropriate for the exposure scenario(s) that are to be considered in the risk assessment. Typically, this will dictate that samples be collected from the surficial soils (i.e., 0–1" depth interval) to assess current exposure scenarios. To assess the risk for future exposure scenarios it may be appropriate to also collect samples at depth. If a large number of samples from different depth intervals are planned, it is suggested to evaluate the correlation in concentration/shot density between depth intervals to determine if samples from the different depth intervals can be combined to reduce sampling costs (U.S. EPA, 2000).

Site conditions (e.g., wetlands) may restrict access to some areas of the site or may increase sampling costs. The sampling plan should account for this to avoid introducing bias into the estimate of the EPC. Samples of other media (e.g., surface water) should be collected as appropriate for the exposure scenarios considered in the risk assessment. Assistance of a statistician to develop the sampling design is recommended.

Sample Preparation. Sieving of soil samples, to evaluate risks, is recommended for two reasons: the fine particle size fraction (<250 μm) is the primary source of soil ingestion (U.S. EPA, 2000) and should be used in predicting risk to humans for the incidental soil ingestion pathway; secondly, sieving will remove lead shot and large bullet fragments from the sample, which are not likely to be ingested inadvertently by humans. It is recommended that soil samples be sieved twice, first with a No. 4 (4.75 mm) or No. 10 (2.00 mm) sieve to remove bulk debris, then with a No. 60 (250 μm) sieve, or smaller sieve size (U.S. EPA, 2000). The No. 4 sieve size recommendation is based on the maximum size shot that is typically used on skeet, trap, and sporting clay ranges (No. 7½), which has a diameter of 2.41 mm. Table B-1 lists the diameters of the pellets for different shot sizes and the size of the openings for different sieve sizes. The portion of the sample that passes through the No. 4 or No. 10 sieve, but retained on the No. 60 sieve, is the 'coarse fraction'; the portion passing through the No. 60 sieve is the 'fine fraction' (U.S. EPA, 2000). The portion of the sample passing through the first sieve (i.e., No. 4 or No. 10) may be referred to as the 'total' sample (i.e., coarse + fine fractions). The 'total' soil concentration may be appropriate for predicting risks to ecological receptors and for predicting risks to humans for future exposure scenarios.

It may be possible to reduce sampling costs by developing a relationship between the coarse and fine sample fractions and use the concentration in one fraction to predict the concentration in the other fraction (U.S. EPA, 2000). However, the coarse fraction will contain fragments from bullets and shot, which will tend to dominate the concentrations measured in the sample. Unless the lead fragments and shot are distributed uniformly across the site it is unlikely that the lead concentration between the coarse and fine fractions will be highly correlated. Increasing the volume of the sample or collecting composite samples may be help to improve the correlation.

Analytical Methods. Samples of the fine fraction should be analyzed for total lead to predict the risk from incidental ingestion of soil. The total fraction should analyzed for total lead to predict the risks from exposure that may occur after the bullet fragments and shot have undergone additional weathering. Solid waste test method 7421 is recommended for measuring the concentration of lead in soil when using fixed-based laboratories for analysis (EPA, 1986b). The use of field-based devices (e.g., X-ray Fluorescence [XRF]) to measure the concentration of lead may be cost-effective and decrease the time to site cleanup. EPA guidance on the use of field-based methods (U.S. EPA, 2001c) should be consulted prior to developing a sampling plan for the site.

Sample Collection at High Velocity Ranges. The horizontal boundaries of active or recently closed pistol and rifle ranges should be fairly obvious; the boundaries of pistol and rifle ranges that have been abandoned for longer periods of time may not be readily apparent from visual inspection alone. Soil samples should be collected from the berm and the rest of the shooting range(s). Samples of other media should be collected, as appropriate, given the exposure scenarios considered in the risk assessment.

Soil sample locations should be determined using random sampling methods that provide adequate coverage of the site, e.g., using systematic or stratified random sampling methods (Gilbert, 1987).

For pistol and rifle ranges, either of these sampling designs may be implemented by sampling on a rectangular or triangular grid. Jacketed bullets typically travel deeper into berms than unjacketed bullets (EA, 1996); the sampling plans for military ranges and other ranges that use jacketed bullets should take this into consideration.

Sample Collection at Low Velocity Ranges. Determining the extent of the area potentially affected by skeet and trap ranges are usually more difficult than it is for pistol and rifle ranges. This is particularly true for closed ranges. Whether the range is active or closed, records of site operations, the location of structures on the range (e.g., traphouse) and information gathered from site inspections can help to prepare a preliminary site layout upon which an initial sampling design can be based.

For skeet and trap ranges, a radial grid, with the origin located behind the shooting positions, may produce a more efficient systematic or stratified random sampling design (e.g., EA, 1995). The highest concentrations of lead are typically found in the top 6–8 inches of soil (EA, 1994, 1995; E&E, 1997;

Murray, 1997); however, elevated concentrations of lead have been detected at 24 inches below grade in skeet and trap range shotfall zones (EEA, 1992; EA, 1995; Murray, 1997).

Lead Risk Modeling Recommendations

This section provides recommendations specific to ranges. General guidance on lead risk assessment, lead models and model documentation can be downloaded from the TRW web site (U.S. EPA, 2002d). The TRW recommends the use of the IEUBK and ALM to predict risk to children and adults, respectively (U.S. EPA, 1994b, 1996). The models are intended to predict risk to humans from exposure to lead that is continuously distributed in various media, including soil. Spent lead ammunition in soil poses a potential risk to humans in two forms: 1) as lead adsorbed or absorbed to soil particles, and as very fine lead particles; and, 2) as lead adsorbed/absorbed to larger soil particles, and as lead shot and bullet fragments. Small soil particles (and by analogy, small lead particles), particularly those <250 μm in size, are the primary source of soil ingestion (EPA, 2000). Lead shot, bullets and large bullet fragments, and large soil particles contaminated with lead, are not likely to be ingested by humans, but represent a source of lead that may be released to the environment through weathering processes. The first form of spent lead ammunition should be considered under the current exposure scenario, while both forms of spent lead ammunition should be considered under future use scenarios.

The IEUBK and the ALM require the user to input an estimate for the EPC for soil; the IEUBK also provides the user with the option of inputting estimates of the EPC for other media: dust, air, drinking water, and diet (e.g., consumption of game and fish with elevated lead concentrations due to exposure to spent lead ammunition). Recommendations are limited here to providing estimates of the EPC for soil; recommendations for other media and model parameters are provided in the IEUBK User's Manual and other guidance that is available on the TRW website (U.S. EPA, 2002d) and the reference list of this paper.

Recommendations for Estimating the Exposure Point Concentration Term. When interpreting analytical data for a shooting range, it is important to distinguish between high and low velocity ranges. As described in beginning of the Site Characterization and Risk Assessment section, soil on high velocity ranges tend to contain very fine particles of lead in addition to bullets and bullet fragments. Soil on low velocity ranges will tend to contain whole and partially decomposed lead pellets. The presence of one bullet, bullet fragment, or lead shot in a soil sample will result in very high measurement of lead concentration which may not yield an accurate prediction of risk for current exposure scenarios (but may be appropriate for future exposure scenarios.

The use of geostatistics may be useful for shooting ranges, particularly skeet and trap ranges, where soil concentrations often exhibit spatial patterns. Geostatistical estimators are capable of exploiting these spatial patterns (i.e., spatial autocorrelation) to determine the extent of contaminated soil, and to produce more precise estimates of the EPC. Another advantage of geostatistical estimators is they can be used with data that have been collected by random and/or non-random sampling methods. Finally, geostatistics can take advantage of the correlation between different types of measurements (e.g., soil concentration and shot count) to obtain more precise estimates of the EPC.

Recommendations for Adjusting Bioavailability. The TRW does not recommend changing the default value for bioavailability without the collection and TRW review of good site-specific data to support such a change. Bioavailability has been shown to be related to lead speciation and soil particle size (U.S. EPA, 1999). While site specific data on lead speciation (e.g., from decomposition of spent ammunition) and particle size are not considered by EPA to be an adequate basis for adjusting the bioavailability variable in the IEUBK or ALM (U.S. EPA, 1999), this information can be used to decide if *in vivo* bioassays are likely to produce estimates of bioavailability that differ substantially from the IEUBK default value. Guidance on the bioavailability variable is available from the TRW website (U.S. EPA, 1999). Based on the available literature on lead speciation in soil on shooting ranges, it appears the default values used in the IEUBK and ALM are appropriate for assessing risks from exposure to soils located on shooting ranges.

Recommendations for Exposure Scenarios. Land use adjacent and near shooting ranges should be considered when developing current and future exposure scenarios. For currently operating sites, the populations of primary concern are residents of adjacent residential properties, residents and farm workers on adjacent agricultural properties, and workers who are employed on adjacent commercial properties. For future use scenarios, the populations of primary concern depend upon the proposed site usage.

BEST MANAGEMENT PRACTICES AND RECYCLING

Guidance for implementing best management practices on small arms outdoor shooting ranges is available from the EPA (EPA, 2001a). Implementing best management practices (BMPs) on ranges decreases the risk of spent ammunition to the environment by recycling spent ammunition; containing lead shot, bullets, and fragments; preventing migration of lead to surface water and groundwater; and keeping records of site operations (U.S. EPA, 2001a). Site conditions (e.g., wetlands, mud, steep slopes, wooded areas) will affect the feasibility of removing spent ammunition from ranges.

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Table A-1. On-line Sources of Information Related to Outdoor Small Arms Shooting Ranges

Agency/Organization	Main Web Address	Topic	Web Address
Fish and Wildlife Service	http://www.fws.gov/	Hunting information	http://birds.fws.gov/Laws.htm
		Fish and Wildlife Management Offices - State, Territorial, and Tribal	http://offices.fws.gov/statelinks.html
Environmental Protection Agency	http://www.epa.gov/	Envirosense PRO-ACT Factsheet on Lead Contamination In Soil at Small Arms Firing Ranges	http://es.epa.gov/program/p2dept/defense/airforce/2818.html
Environmental Protection Agency	http://www.epa.gov/	Military Munitions Rule, Federal Register. February 12, 1997. Volume 62, Number 29. Page 6621-6657	http://www.epa.gov/docs/fedrgstr/EPA-WASTE/1997/February/Day-12/f3218.htm
Environmental Protection Agency (EPA) - Region 2	http://www.epa.gov/	Best Management Practices for Lead at Outdoor Shooting Ranges	http://www.epa.gov/region2/waste/leadshot/
PROACT (Department of Defense)	http://www.afcee.brooks.af.mil/pro-act/PRO-ACThome.asp	Factsheet on lead contamination in soil at small arms firing ranges	http://www.afcee.brooks.af.mil/pro-act/fact/june98a.asp

Agency	Main Web Address	Topic	Web Address
Alabama Department of Conservation and Natural Resources	http://www.dcnr.state.al.us/agfd/index.html	Legal arms and ammunition for hunting	http://www.dcnr.state.al.us/agfd/arms.html
Florida Fish and Wildlife Conservation Commission	http://floridaconservation.org/	Public shooting ranges	http://floridaconservation.org/huntered/ranges.html
		Hunting information and regulations	http://www.wld.fwc.state.fl.us/hunting/default.html
Idaho Fish and Game	http://www2.state.id.us/fishgame/common/50list.htm	50 State Fish and Game Agencies List	http://www2.state.id.us/fishgame/common/50list.htm
Massachusetts Division of Fisheries, Wildlife and Environmental Law Enforcement	http://www.state.ma.us/dfwele/dpt_toc.htm	Lead shot in the environment	http://www.state.ma.us/dep/files/pbshot/pb_shot.htm
		Wildlife recreation information; hunting and fishing laws	http://www.state.ma.us/dfwele/dfw/dfwrec.htm#LAWS
Michigan Department of Environmental Quality	http://www.michigan.gov/deq/	Environmental regulations affecting shooting ranges	http://www.michigan.gov/deq/1,1607,7-135-3585_4127_13090-25492--,00.html
Ohio Environmental Protection Agency	http://www.epa.state.oh.us/	List of lead reclaimers	http://www.epa.state.oh.us/dhwm/leadrecy.htm
Tennessee Wildlife Resources Agency	http://www.state.tn.us/twra/index.html	Legal hunting equipment and methods	http://www.state.tn.us/twra/hunt001a3.html
National Shooting Sports Foundation (NSSF)	http://www.huntinfo.org/	Summaries of every state's hunting opportunities and regulations and links to state fish and game websites	http://www.huntinfo.org/

Agency	Main Web Address	Topic	Web Address
		Search page to find shooting ranges	http://www.wheretoshoot.org/
National Association of Shooting Ranges (NASR)	http://www.rangeinfo.org/	Includes references and sources of information on outdoor shooting ranges	http://www.rangeinfo.org/
National Sporting Clays Association	http://WWW.NSSA-NSCA.COM/nsca/index.htm	Search page to find shooting ranges	http://WWW.NSSA-NSCA.COM/nsca/index.htm
		Links to shooting-related sites	http://www.nssa-nsca.com/common/shooting_sites.htm
Sporting Arms and Ammunition Manufacturer's Institute, Inc. (SAAMI)	http://www.saami.org/	General source of information on shooting ranges	http://www.saami.org/
Miscellaneous	http://dir.yahoo.com/Recreation/Outdoors/Hunting/Organizations/	List of hunting organizations	http://dir.yahoo.com/Recreation/Outdoors/Hunting/Organizations/
National Wild Turkey Federation	http://www.shooting-hunting.com/index.html	search page for shooting ranges	http://www.shooting-hunting.com/results.html?Keywords=Shooting+Range

Table B-1. Shot Size and EPA-Recommended Sieve Sizes for Use at Small Arms Outdoor Firing Ranges

Shot Size	Pellet Diameter	
	Inches	Millimeters
Buckshot		
No. 000 - No. 2	.36 - .27	9.14 - 6.86
No. 3	.25	6.35
No. 4	.24	6.10
Shot		
F	.22	5.59
T	.20	5.08
BBB	.19	4.83
A No. 4 Sieve (0.19 inch/4.76 mm openings) will remove the shot sizes listed above.		
BB	.18	4.57
1	.16	4.06
2	.15	3.81
3	.14	3.56
4	.13	3.30
5	.12	3.05
6	.11	2.79
7	.10	2.54
7 ½	.095	2.41
8	.09	2.29
8 ½	.085	2.16
9	.08	2.03
A No. 10 Sieve (0.08 inch/2.00 mm openings) will remove the shot sizes listed above		
A No. 60 (0.25 mm openings) sieve, or smaller sieve size, is recommended to prepare the 'fine' soil fraction for analysis (see 'Sample Preparation' section)		

Note: Shot size is generally limited to a maximum of no. 7 ½ for trap and sporting clay use, and a maximum of no. 7 ½ and minimum of no. 9 for skeet shooting.

EPA
OSWER #9285.7-52
March 2002

BLOOD LEAD CONCENTRATIONS OF U.S. ADULT FEMALES: SUMMARY STATISTICS FROM PHASES 1 AND 2 OF THE NATIONAL HEALTH AND NUTRITION EVALUATION SURVEY (NHANES III)

Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Washington, DC 20460

NOTICE

This document provides guidance to EPA staff. It also provides guidance to the public and to the regulated community on how EPA intends to exercise its discretion in implementing the National Contingency Plan. The guidance is designed to implement national policy on these issues. The document does not, however, substitute for EPA's statutes or regulations, nor is it a regulation itself. Thus, it cannot impose legally-binding requirements on EPA, States, or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA may change this guidance in the future, as appropriate.

U.S. Environmental Protection Agency
Technical Review Workgroup for Lead

The Technical Review Workgroup for Lead (TRW) is an interoffice workgroup convened by the U.S. EPA Office of Solid Waste and Emergency Response/Office of Emergency and Remedial Response (OSWER/OERR).

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Blood Lead Concentrations of U.S. Adult Females: Summary Statistics from Phases 1 and 2 of the National Health and Nutrition Evaluation Survey (NHANES III)

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Contract No. GS-10F-0137K
FEDSIM Order No. DABT63-01-F-0133-00
SRC No. FA332

1.0 Introduction

In 1996 the Technical Review Workgroup for Lead (TRW) provided guidance for assessing lead risks to adults from exposures to lead in soil. The Adult Lead Methodology (ALM) (U.S. EPA, 1996) includes two parameters that are the subject of this report. The background blood lead concentration ($PbB_{adult,0}$) represents the typical blood lead concentration (PbB) (µg/dL) in women of child-bearing age, in the absence of exposures at the site being assessed. The parameter $GSD_{i,adult}$, is the estimated value of the individual geometric standard deviation (GSD); the GSD among adults (i.e., women of child-bearing age) that have exposures to similar on-site lead concentrations. Default values for both $PbB_{adult,0}$ and $GSD_{i,adult}$ were derived from an analysis of blood lead data for women 17–45 years of age, from Phase 1 of the Third National Health and Nutrition Evaluation Survey (NHANES III, Phase 1) as well as consideration of available site-specific data on PbB GSDs (U.S. EPA, 1996). Based on those analyses the following default values ranges were recommended: $PbB_{adult,0}$, 1.7–2.2 µg/dL and $GSD_{i,adult}$, 1.9–2.1.

Data from Phase 2 of the NHANES III became available subsequent to the latter analysis. The NHANES III survey was designed to be completed in two phases; while unbiased estimates of population parameters may be obtained using data from either phase separately, more precise estimates are obtained from combining the two phases (CDC, 1996a). Therefore, the availability of the complete NHANES III data prompted a reexamination of the basis for the default values for these two parameters, the results of which are provided in this report. The analysis reported here estimates the geometric mean (GM) and GSD of PbBs of U.S. non-institutionalized women between the ages 17–45 years based on data collected in Phases 1 and 2 of the NHANES. As was the approach taken in 1996, estimates were made for the major race/ethnicity categories represented in the NHANES III survey: non-Hispanic white, non-Hispanic black, Mexican-American, and *Other*. Additionally, results of the combined Survey Phases are presented separately for each of the regional quadrants of the NHANES Survey.

Decreases in estimates of GM PbBs observed between Phases 1 and 2 are offset by increases in the GSD. The net effect is that the ranges of Preliminary Remediation Goals (PRGs) calculated using the ALM do not differ appreciably between the two phases.

Technical Approach: Information on age, race/ethnicity, and PbB concentration for adults 17–45 years of age was extracted from the NHANES III database (CDC, 1997). Data from both phases of the NHANES III was used in this analysis in accordance with CDC recommendations (CDC, 1996a). An accurate estimate for the GM from any subset of the PbB concentrations can be made by using the sample weights included in the NHANES III database. To obtain an accurate estimate for the GSD from a subset of the PbB concentrations, however, is more complicated because the mathematical formula that is used to calculate a GSD is not linear. When estimating a measure of variability, such as the GSD, the sample weights provided in NHANES do not fully account for the complex sampling design used in NHANES III. Furthermore, the nature and degree of bias in the estimate of a GSD that is calculated using only the sample weights are unknown. To partially address this source of uncertainty, two approaches were used to estimate the GSD as described below.

In the first approach, estimates for the GM and GSD were obtained using SAS (release 8.00, SAS Institute Inc.) and the sample weights recommended by CDC (1996a); this was the same approach used in the analysis of the NHANES Phase 1 data (U.S. EPA, 1996). Standard errors for the estimates of the GM PbB were estimated using SUDAAN (version 7.5, a program that is implemented within SAS).

In the second approach, a lognormal probability plot was created using the empirical cumulative distribution (ECD) (i.e., percentiles) estimated with SUDAAN for each race/ethnicity group defined in NHANES III. The ECDs were estimated using SUDAAN. SUDAAN is designed to compute statistics (e.g., means and percentiles) and their standard errors for data derived from complex sample surveys such as the NHANES III. (SUDAAN does not calculate estimates of population variance, such as the GSD.) The analysis utilizes the sample weights and pseudo-primary sampling units and pseudo-stratums provided in the NHANES III (CDC, 1996a). The sample weights incorporate the differential probabilities of selection of survey participants and include adjustments for non-coverage and non-response. The pseudo-primary sampling units and pseudo-stratums account for the multistage sampling design and are necessary to estimate accurate standard errors of parameter estimates.

The GM PbB and GSD estimated from the probability plots were compared to those estimated directly from NHANES III with SUDAAN and SAS as a qualitative check on the curve fitting procedure. A quantitative check on the curve fitting is provided by the coefficient of determination (R^2) that is reported for each probability plot.

2.0 Results

Table 1 presents the percentiles of PbB estimated for U.S. women, 17–45 years of age, stratified by race/ethnicity, along with their standard errors and 95% confidence intervals. Table 2 presents estimates of the GM PbB and GSD, stratified by race/ethnicity. The values of the GM estimated from the probability plots (Figures 1–5) were close to those estimated directly from NHANES III using SUDAAN, although they were consistently higher (by an average of 0.03 µg/dL). The values of GSD estimated from the probability plots were close to the those estimated using SAS, however, the values of GSD estimated from the probability plots are consistently lower (by an average of 0.10 µg/dL).

The probability plots and the close agreement between the estimates of the GM and GSD based on the two approaches is a qualitative indication that the lognormal distribution is a reasonable model for the PbBs included in this analysis. A more quantitative indication is provided by the high R^2s shown in Figures 1–5.

The results indicate that the GM PbB for the non-Hispanic black and Mexican-American race/ethnicity groups are greater than the GMs for the non-Hispanic white group and the combined groups. The results also indicate greater variability in the PbBs of the Mexican-American group than the non-Hispanic black, non-Hispanic white, or combined groups. These outcomes are consistent with the results obtained from the analysis of Phase 1 of the NHANES (U.S. EPA, 1996). Due to the small sample size and related high uncertainty, the results shown for the *Other* race/ethnicity group should be interpreted with caution (CDC, 1996a).

Table 3a shows the GM and GSD by census regions and race/ethnicity. Figure 6 shows the delineation of the states into the four census regions (U.S. Census Bureau, 2001). In these analyses, GSDs were estimated using SAS. The pattern of higher GM in non-Hispanic blacks and Mexican Americans than in non-Hispanic whites persisted when data were stratified by geographic quadrant. The GMs for all race/ethnicity categories were higher in the northeast quadrant than in other quadrants. GSDs for the non-Hispanic whites and *Other*s groups were relatively consistent across quadrants; the GSDs for non-Hispanic black and Mexican-American groups varied from 1.9–2.2 and 1.9–2.4, respectively. The lowest GSDs for each race/ethnicity group occurred in the northeast quadrant, while the highest GSDs are found in the midwest region. The Mexican-American race/ethnicity group has the largest GSD for each census region, with the exception of the northeast. The GM and GSD estimated for Mexican-Americans in the northeast region should be interpreted with caution due to the low sample number (24).

In Tables 3b and 3c the 17–45 year age group was further divided into three age groups: 17–25, 26–35, and 36–45. Table 3b shows the GM and GSD by the three age categories and race/ethnicity; Table 3c shows the GM and GSD by the three age categories and census region. Table 3b shows the GM PbB for all race/ethnicity groups combined increases with age; this pattern is also observed within each of the race/ethnicity groups. The pattern of higher GM in non-Hispanic blacks and Mexican Americans persisted when data were stratified by age groups. Estimates of the GSD across age groups for all race/ethnic groups combined varied by only 0.02. Variance of the estimated GSDs across age groups increases once the data is stratified by race-ethnicity.

Table 3c shows the trend of higher GM PbBs in the northeast persisted after the data were stratified by age groups. Table 3c also shows the largest increase in GM PbBs across age groups occurs in the Midwest, followed by the Northeast, West, and South. Estimates of the GSD across age groups and within census region varied by 0.01–0.02.

3.0 Discussion and Conclusions

3.1 Sources of Uncertainty

Table 4 shows the occurrence of non-detects for each of the two phases of the NHANES III and for both phases combined. The percentage of non-detects for the combined race/ethnicity groups was 21% and ranged from 17% for the non-Hispanic black group to 28% for the non-Hispanic white group. The increase in the overall rate of non-detects between Phases 1 and 2 was 7.3% and was fairly consistent across the different race/ethnicity groups. In this analysis, non-detects were set equal to ½ the detection limit of 1.0 μg/dL, which is consistent with other reported analyses of PbB concentrations from the NHANES III (Brody et al., 1994). Preliminary analysis indicated the estimates of GM PbB and GSD are highly sensitive to values assigned to non-detects. Estimates of the GM/GSD for all of the race/ethnicity groups combined were 1.8/1.7, 1.5/2.1, and 1.3/2.7 when non-detects were set equal to the detection limit of 1.0 μg/dL, ½ the detection limit, and 1/4 the detection limit, respectively. The sensitivity of the parameter estimates to the method used to treat non-detects should be considered in interpreting differences between parameter values estimated with different approaches or with different subsets of the NHANES III data. Furthermore, the impact of the uncertainty related to the treatment of detection limits will increase if the trend of decreasing PbB continues, unless the detection limits are lowered.

As previously discussed, the method used to estimate the PbB GSD does not fully account for the complex sampling design employed in the NHANES III. Research would be required to determine how to calculate more accurate estimates of the GSD and its standard error. It is not clear if such an effort would be of great value, in terms of reducing uncertainty in the GSD estimate. NHANES III is a well designed study and relatively large sample sizes were available for developing the GSD estimates. The more consequential issue for risk assessment is variation of the GSD between population subgroups as compared with the uncertainty in the estimates of GSD.

Based on this analysis and the above considerations, the lognormal distribution appears to provide an adequate model for distribution of PbBs for non-institutionalized U.S. women, 17–45 years of age. The results obtained from the probability plots were similar to those obtained with the direct computation of the GM and GSD; thus, either approach appears to be reasonable and adequate for parameter estimation. However, direct computation from the NHANES III is recommended as the preferred approach, due to its simplicity. Estimates for the PbB GM (point estimates and confidence intervals) and GSD, based on the direct computation approach, are discussed in the remainder of this report (confidence intervals for GSD could not be calculated with the approaches used in this analysis).

3.2 COMPARISON OF 1996 DEFAULT VALUES AND UPDATED RANGES BASED ON NHANES PHASES 1 AND 2

The purpose of this analysis was to incorporate data from Phase 2 of the NHANES III survey in the estimates of the GM and GSD of PbB in the non-institutionalized U.S. women, 17–45 years of age. This is consistent with the recommendations of the CDC (1996a); incorporation of the phase 2 data will tend to increase confidence in the estimates of the GM and GSD of the distribution of PbB in non-institutionalized U.S. women, 17–45 years of age.

Comparisons of the values for the GM PbB and GSD based on the data from the combined Phases 1 and 2 of the NHANES III with the values estimated from the NHANES III Phase 1 (U.S. EPA, 1996) and the default values for $PbB_{adult,0}$ and $GSD_{i,adult}$ used in the EPA ALM (U.S. EPA, 1996) are presented in Table 5. Several observations can be made from these comparisons:

a. Both the EPA ALM default value range for $PbB_{adult,0}$ (1.7–2.2) and the range of GM PbB based on the NHANES III Phase 1 data (1.7–2.1), lie outside and above the 95% confidence intervals for the GM PbB estimated from the combined data from the NHANES III phases 1 and 2 (1.4–1.9). Thus, the combined data from Phases 1 and 2 of the NHANES III suggest a lower GM PbB than previously reported in the EPA ALM documentation (U.S. EPA, 1996).

b. Both the upper end of the range of the EPA ALM default values for $GSD_{i,adult}$ and the upper end of the race/ethnicity range for the GSD estimated from the NHANES III Phase 1 data match the lower end of the race/ethnicity range for the GSD estimated from the combined data from the NHANES III Phases 1 and 2. Thus, the combined data from Phases 1 and 2 of the NHANES III suggest a higher GSD than previously reported in the EPA ALM documentation (U.S. EPA, 1996).

c. The above results support several updated value ranges for $PbB_{adult,0}$ for use in the EPA ALM, depending upon how the results are stratified. Stratifying the data by race/ethnicity groups, two reasonable ranges for $PbB_{adult,0}$ are: 1) 1.4–1.8 μg/dL, the range of the estimated GMs for the three major race/ethnicity groups; and 2) a more conservative and equally supportable range would be 1.6–1.9, the range of the 95% upper confidence limits of the GM for the major race/ethnicity groups.

d. Stratifying the data by census regions, reasonable updated ranges for $PbB_{adult,0}$ are: 1) 1.4–2.0 μg/dL, the range of the estimated GMs for the four census regions; and 2) a more conservative and equally supportable range would be 1.5–2.2, the range of the 95% upper confidence limits of the GM for the four census regions.

e. The results also support use of an updated value ranges for $GSD_{i,adult}$ in the EPA ALM. Stratifying the data by race/ethnicity groups, a reasonable range for $GSD_{i,adult}$ is 2.1–2.3.

f. Stratifying the data by census regions, a reasonable updated range for $GSD_{i,adult}$ is 2.0–2.2.

3.3 Impacts of Updated Value Ranges for $PbB_{ADULT,0}$ and $GSD_{i,ADULT}$ on PRGs Calculated with the EPA ALM

Table 3a contains preliminary remediation goals calculated with the EPA ALM, by census region and race/ethnicity, using the estimated GMs and GSDs for the respective regions and race/ethnicity groups.

a. The range for the PRGs established in 1996, based on the range of GMs and GSDs provided in the ALM (Table 6), is 749–1754 μg Pb/g soil (ppm).

b. Based on the range of values shown for the major race/ethnicity groups in Table 3a (i.e., for "All Regions"), the range of the PRGs decreased considerably to 794–1,288 ppm.

c. Based on the range of values shown for the census regions in Table 3a, the range of the PRGs decreased, but is shifted higher, to 1,079–1,366 ppm.

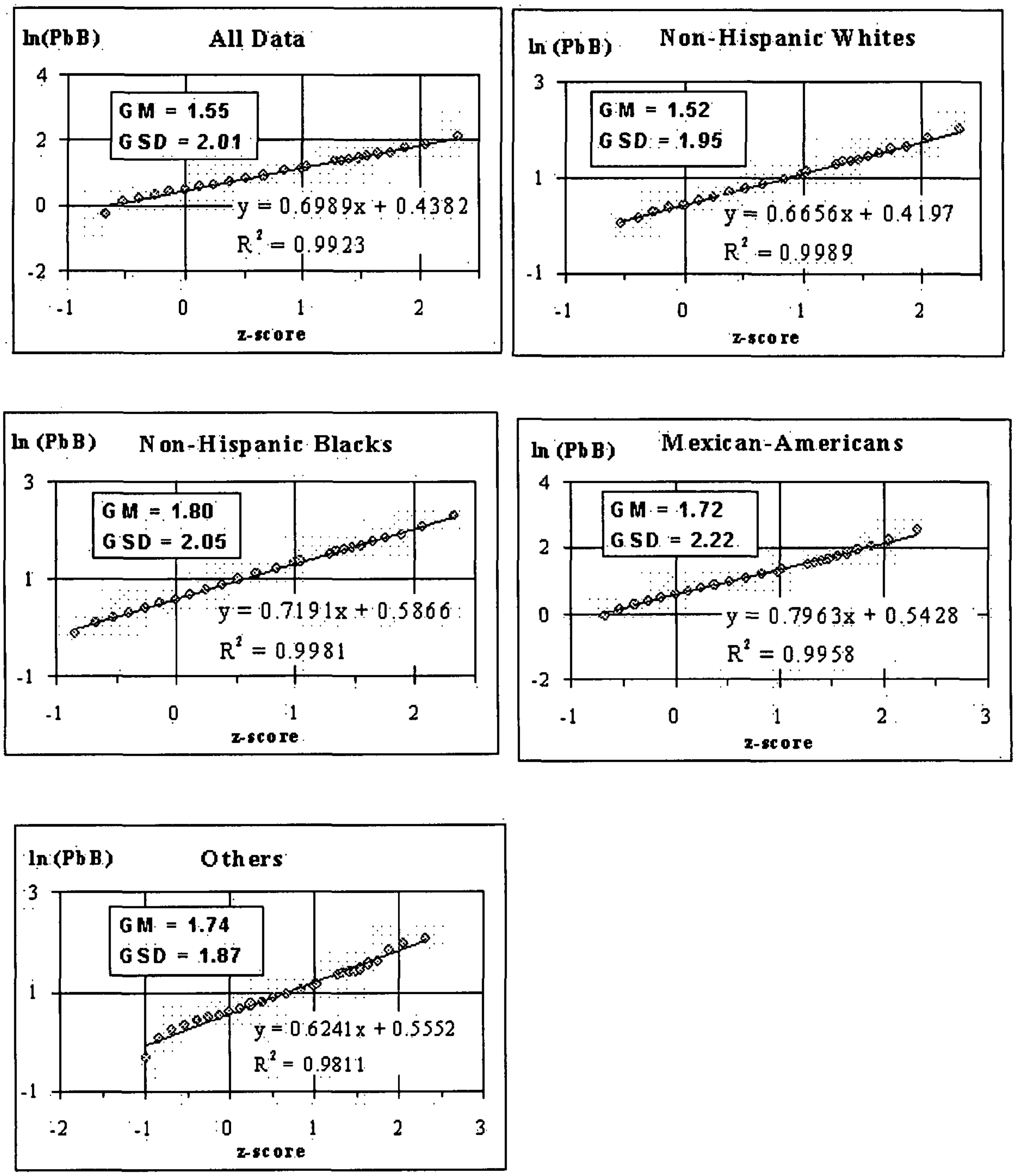
The similarity in the PRG ranges that are calculated, when each of the $PbB_{adult,0}$ and $GSD_{i,adult}$ ranges are assumed, suggests that use of the updated ranges for these parameters, although reasonably supported by the NHANES III, may not produce a large change in the PRG calculated at any given site.

3.4 Recommendations

Previous recommendations for the Interim Adult Lead Model were presented, in aggregate as well as separately, for the racial/ethnic categories used by the NHANES III survey. This revision retains the previous racial/ethnic categories and also presents the GM and GSD for each of the four geographic quadrants delineated by NHANES III. For site applications of the ALM, estimates of the $PbB_{adult,0}$ and $GSD_{i,adult}$ parameters could be based on either race/ethnicity or geographic categories determined appropriate based on the specific demographic or geographic characteristics of the site. Perceived gains in specificity achieved from stratifying on both demographic and geographic characteristics may be offset by increased uncertainty caused by using less of the available survey data. This uncertainty is evident in the reduction of sample size and increased standard errors in the PbB (GM). Unfortunately, corresponding uncertainty in the estimates of the GSD is not quantifiable by usual methods due to the complex sampling design used in NHANES III.

Estimates for $PbB_{adult,0}$ (GM) and $GSD_{i,adult}$ (GSD) by census region and race/ethnicity group are provided for information. However, it is not recommended to base estimates of the $PbB_{adult,0}$ and $GSD_{i,adult}$ from the NHANES III survey that are stratified by both census region and race/ethnicity group in the ALM to estimate site-specific risks because of the small sample sizes, particularly in the Northeast and Midwest regions (e.g., $n = 157$ for Mexican-Americans in the Midwest region). The small sample sizes are reflected in the large standard errors for the GM in those regions (relative to the South and West regions). In addition to race/ethnicity and census region, other factors that should be considered when selecting an estimate for the $PbB_{adult,0}$ and $GSD_{i,adult}$ include characteristics of current and anticipated future exposed populations, age of the housing stock in the area of the site and other potential sources of lead (e.g., industrial discharges).

Based on this analysis, updated ranges for the $PbB_{adult,0}$ and $GSD_{i,adult}$ parameters in the EPA ALM are supported by the data collected in the completed NHANES III survey (Phases 1 and 2). Although the use of these updated ranges in the EPA ALM may not appreciably change PRGs calculated with the methodology, it is recommended that data from both phases of NHANES III be used in all PbB analyses; this is consistent with the CDC's recommendation (CDC, 1996a).



FIGURES 1–5. Probability plots were prepared from the log-transformed percentiles estimated with SAS-SUDAAN. The geometric mean (GM) was estimated by exp (intercept) and the geometric standard deviation (GSD) was estimated by exp (Slope). The GM and GSD estimated with this method compare favorably with the estimates produced with SAS-SUDAAN. The mean difference between the GMs estimated by the two methods is approximately 0.03; the mean difference in the GSDs is approximately 0.10.

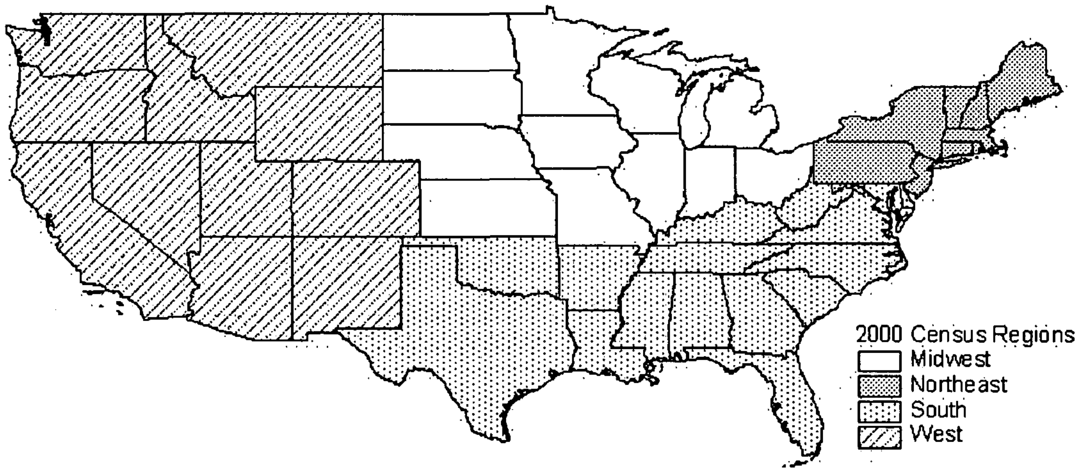


FIGURE 6. Grouping of States into the Four U.S. Census Regions. Hawaii and Alaska (not shown) are in the West Region.

TABLE 1. Estimated Cumulative Distribution Function of Blood Lead Concentration (µg/dL) in U.S. Women, 17–45 years of Age					
Race/ethnicity	Percentile	CTE[a]	SE[b]	95th LCL[c]	95th UCL[c]
All (n = 5016)	minimum[d]	0.5[e]	na[f]	na	na
	5	–[g]	–	–	–
	10	–	–	–	–
	15	–	–	–	–
	20	–	–	–	–
	25	0.77	0.10	0.58	0.97
	30	1.11	0.03	1.05	1.16
	35	1.25	0.03	1.19	1.30
	40	1.38	0.02	1.34	1.43
	45	1.49	0.02	1.45	1.53
	50	1.61	0.02	1.56	1.66
	55	1.75	0.03	1.70	1.81
	60	1.89	0.03	1.83	1.95
	65	2.06	0.03	2.00	2.11
	70	2.22	0.03	2.16	2.28
	75	2.47	0.04	2.39	2.54
	80	2.81	0.05	2.71	2.90
	85	3.22	0.07	3.09	3.36
	90	3.81	0.05	3.71	3.90
	91	3.89	0.05	3.80	3.98
	92	4.05	0.07	3.90	4.19
	93	4.26	0.08	4.10	4.42
	94	4.52	0.09	4.33	4.71
	95	4.84	0.12	4.61	5.07
	96	5.11	0.09	4.94	5.28
	97	5.73	0.18	5.37	6.09
	98	6.50	0.16	6.17	6.83
	99	8.13	0.14	7.86	8.41
	maximum[h]	29.2	na	na	na

[a]CTE: central tendency estimate
[b]SE: standard error of the estimate (balanced repeated replication method)
[c]95th LCL/UCL: lower/upper 95th % confidence limits for the estimated percentile
[d]Minimum value shown is the value assigned to non-detects (i.e., ½ detection limit of 1 µg/dL)
[e]The value 0.5 is the value assigned to non-detects; the limit of detection for blood lead concentration reported by CDC is 1.0 ug/dL (CDC, 1996b).
[f]na: not applicable
[g]Indicates the presence of non-detects prevented an estimate of the percentile and its standard error
[h]Maximum value shown is the observed values extracted from the NHANES III database; it is not an estimate.

TABLE 1. Estimated Cumulative Distribution Function of Blood Lead Concentration (µg/dL) in U.S. Women, 17–45 years of Age—*Continued*					
Race/ethnicity	Percentile	CTE[a]	SE[b]	95th LCL[c]	95th UCL[c]
non-Hispanic white	minimum[d]	0.5[e]	na[f]	na	na
	5	-[g]	–	–	–
(*n*= 1529)	10	–	–	–	–
	15	–	–	–	–
	20	–	–	–	–
	25	–	–	–	–
	30	1.03	0.05	0.92	1.14
	35	1.18	0.03	1.11	1.25
	40	1.32	0.03	1.25	1.39
	45	1.44	0.02	1.39	1.49
	50	1.54	0.03	1.48	1.59
	55	1.67	0.04	1.60	1.74
	60	1.82	0.03	1.75	1.88
	65	1.97	0.04	1.89	2.04
	70	2.13	0.03	2.06	2.19
	75	2.31	0.05	2.21	2.42
	80	2.64	0.07	2.50	2.78
	85	3.06	0.08	2.90	3.22
	90	3.61	0.07	3.47	3.76
	91	3.74	0.06	3.62	3.87
	92	3.84	0.05	3.74	3.94
	93	3.98	0.09	3.81	4.16
	94	4.23	0.11	4.01	4.44
	95	4.52	0.09	4.33	4.71
	96	4.89	0.14	4.61	5.18
	97	5.20	0.17	4.86	5.53
	98	6.03	0.20	5.62	6.43
	99	7.41	0.42	6.57	8.26
	maximum[h]	12.4	na	na	na

[a]CTE: central tendency estimate
[b]SE: standard error of the estimate (balanced repeated replication method)
[c]95th LCL/UCL: lower/upper 95th % confidence limits for the estimated percentile
[d]Minimum value shown is the value assigned to non-detects (i.e., ½ detection limit of 1 µg/dL)
[e]The value 0.5 is the value assigned to non-detects; the limit of detection for blood lead concentration reported by CDC is 1.0 ug/dL (CDC, 1996b).
[f]na: not applicable
[g]Indicates the presence of non-detects prevented an estimate of the percentile and its standard error
[h]Maximum value shown is the observed values extracted from the NHANES III database; it is not an estimate. .

TABLE 1. Estimated Cumulative Distribution Function of Blood Lead Concentration (μg/dL) in U.S. Women, 17–45 years of Age—*Continued*					
Race/ethnicity	Percentile	CTE[a]	SE[b]	95th LCL[c]	95th UCL[c]
non-Hispanic black	minimum[d]	0.5[e]	na[f]	na	na
	5	–[g]	–	–	–
(*n* = 1692)	10	–	–	–	–
	15	–	–	–	–
	20	0.89	0.11	0.67	1.10
	25	1.13	0.03	1.07	1.19
	30	1.25	0.03	1.20	1.31
	35	1.38	0.04	1.30	1.46
	40	1.52	0.05	1.43	1.61
	45	1.66	0.04	1.57	1.74
	50	1.79	0.05	1.69	1.89
	55	1.95	0.06	1.83	2.08
	60	2.16	0.07	2.02	2.30
	65	2.40	0.08	2.23	2.57
	70	2.69	0.08	2.54	2.85
	75	3.03	0.08	2.88	3.19
	80	3.37	0.13	3.11	3.63
	85	3.87	0.11	3.65	4.09
	90	4.53	0.16	4.21	4.86
	91	4.75	0.13	4.48	5.01
	92	4.91	0.12	4.68	5.15
	93	5.11	0.12	4.86	5.36
	94	5.28	0.23	4.81	5.75
	95	5.76	0.23	5.30	6.22
	96	6.25	0.21	5.83	6.68
	97	6.71	0.25	6.21	7.21
	98	7.84	0.30	7.25	8.43
	99	9.77	0.77	8.22	11.32
	maximum[h]	20.3	na	na	na

[a]CTE: central tendency estimate
[b]SE: standard error of the estimate (balanced repeated replication method)
[c]95th LCL/UCL: lower/upper 95th % confidence limits for the estimated percentile
[d]Minimum value shown is the value assigned to non-detects (i.e., ½ detection limit of 1 μg/dL)
[e]The value 0.5 is the value assigned to non-detects; the limit of detection for blood lead concentration reported by CDC is 1.0 ug/dL (CDC, 1996b).
[f]na: not applicable
[g]Indicates the presence of non-detects prevented an estimate of the percentile and its standard error
[h]Maximum value shown is the observed values extracted from the NHANES III database; it is not an estimate.

TABLE 1. Estimated Cumulative Distribution Function of Blood Lead Concentration (μg/dL) in U.S. Women, 17–45 years of Age—*Continued*					
Race/ethnicity	Percentile	CTE[a]	SE[b]	95th LCL[c]	95th UCL[c]
Mexican - American (*n* = 1562)	minimum[d]	0.5[e]	na[f]	na	na
	5	-[g]	–	–	–
	10	–	–	–	–
	15	–	–	–	–
	20	–	–	–	–
	25	0.92	0.11	0.70	1.15
	30	1.14	0.03	1.07	1.21
	35	1.31	0.05	1.22	1.40
	40	1.47	0.04	1.40	1.55
	45	1.63	0.04	1.54	1.71
	50	1.81	0.05	1.72	1.90
	55	1.97	0.05	1.88	2.07
	60	2.16	0.05	2.07	2.26
	65	2.37	0.05	2.26	2.48
	70	2.59	0.06	2.48	2.70
	75	2.90	0.07	2.75	3.05
	80	3.29	0.08	3.14	3.44
	85	3.79	0.10	3.59	3.99
	90	4.51	0.13	4.24	4.77
	91	4.74	0.16	4.42	5.06
	92	5.02	0.16	4.70	5.34
	93	5.34	0.20	4.94	5.75
	94	5.77	0.20	5.37	6.18
	95	6.26	0.34	5.58	6.94
	96	7.11	0.35	6.41	7.81
	97	7.85	0.40	7.05	8.66
	98	9.15	0.37	8.41	9.88
	99	12.29	0.97	10.34	14.23
	maximum[h]	29.2	na	na	na

[a]CTE: central tendency estimate
[b]SE: standard error of the estimate (balanced repeated replication method)
[c]95th LCL/UCL: lower/upper 95th % confidence limits for the estimated percentile
[d]Minimum value shown is the value assigned to non-detects (i.e., ½ detection limit of 1 μg/dL)
[e]The value 0.5 is the value assigned to non-detects; the limit of detection for blood lead concentration reported by CDC is 1.0 ug/dL (CDC, 1996b).
[f]na: not applicable
[g]Indicates the presence of non-detects prevented an estimate of the percentile and its standard error
[h]Maximum value shown is the observed values extracted from the NHANES III database; it is not an estimate.

TABLE 1. Estimated Cumulative Distribution Function of Blood Lead Concentration (μg/dL) in U.S. Women, 17–45 years of Age—*Continued*					
Race/ethnicity	Percentile	CTE[a]	SE[b]	95th LCL[c]	95th UCL[c]
other racial-ethnic groups (*n* = 233)	minimum[d]	0.5[e]	na[f]	na	na
	5	–[g]	–	–	–
	10	–	–	–	–
	15	–	–	–	–
	20	1.07	0.18	0.71	1.42
	25	1.24	0.09	1.06	1.42
	30	1.37	0.06	1.25	1.50
	35	1.52	0.07	1.38	1.66
	40	1.63	0.05	1.53	1.72
	45	1.72	0.05	1.63	1.81
	50	1.81	0.05	1.71	1.92
	55	1.92	0.07	1.78	2.06
	60	2.06	0.07	1.92	2.20
	65	2.20	0.09	2.02	2.39
	70	2.39	0.08	2.23	2.55
	75	2.52	0.11	2.31	2.74
	80	2.80	0.13	2.53	3.06
	85	3.09	0.32	2.45	3.73
	90	3.88	0.13	3.62	4.13
	91	3.93	0.12	3.69	4.17
	92	3.99	0.12	3.74	4.24
	93	4.11	0.15	3.80	4.42
	94	4.28	0.25	3.78	4.77
	95	4.71	0.36	3.99	5.42
	96	5.03	0.51	4.02	6.05
	97	6.21	0.95	4.30	8.12
	98	7.09	0.89	5.30	8.87
	99	7.86	0.62	6.61	9.10
	maximum[h]	9.20	na	na	na

[a]CTE: central tendency estimate
[b]SE: standard error of the estimate (balanced repeated replication method)
[c]95th LCL/UCL: lower/upper 95th % confidence limits for the estimated percentile
[d]Minimum value shown is the value assigned to non-detects (i.e., ½ detection limit of 1 μg/dL)
[e]The value 0.5 is the value assigned to non-detects; the limit of detection for blood lead concentration reported by CDC is 1.0 ug/dL (CDC, 1996b).
[f]na: not applicable
[g]Indicates the presence of non-detects prevented an estimate of the percentile and its standard error
[h]Maximum value shown is the observed values extracted from the NHANES III database; it is not an estimate.

TABLE 2. Estimated Geometric Means and Geometric Standard Deviations of Blood Lead Concentration (μg/dL) in U.S. Women, 17–45 Years of Age							
Race/ ethnicity[a]	*n*	GM[b] (prob plot)	GM[c] (SUDAAN)	GM SE[d] (SUDAAN)	GSD[e] (prob plot)	GSD[f] (SAS)	R^2
All	5016	1.55	1.53	0.05	2.01	2.11	>0.99
non-Hispanic white	1529	1.52	1.45	0.06	1.95	2.09	>0.99
non-Hispanic black	1692	1.80	1.78	0.06	2.05	2.16	>0.99
Mexican-American	1562	1.72	1.70	0.06	2.22	2.29	>0.99
Other	233	1.74	1.74	0.11	1.87	1.97	>0.98

[a]Race-Ethnicity categories provided in NHANES III
[b]GM: Estimates of the geometric mean PbB estimated from the log probability plots (Figures 1-5).
[c]GM: Estimates of the geometric mean PbB estimated directly from NHANES III using SUDAAN software.
[d]GM SE: Standard error of the geometric mean estimated with SUDAAN (Taylor series method).
[e]GSD: Geometric standard deviation estimated from the log probability plots (Figures 1-5).
[f]GSD: Geometric standard deviation estimated directly from NHANES III using SAS and the WTPFEX6 sample weight.
[g]R^2: Coefficient of variation from the probability plots shown in Figures 1–5.

TABLE 3a. Estimated Geometric Means and Geometric Standard Deviations of Blood Lead Concentration (μg/dL) in U.S. Women, 17 - 45 Years of Age, By Census Region and Race/Ethnicity

All Regions					
Race/Ethnicity[a]	*n*	GM[b]	GM SE[c]	GSD[d]	PRG[e]
All	5016	1.53	0.05	2.11	1,197
non-Hispanic white	1529	1.45	0.06	2.09	1,288
non-Hispanic black	1692	1.78	0.06	2.16	938
Mexican-American	1562	1.70	0.06	2.29	794
Other	233	1.74	0.11	1.97	1,321
Northeast Region					
Race/Ethnicity[a]	*n*	GM[b]	GM SE[c]	GSD[d]	PRG[e]
All	629	1.98	0.16	2.00	1,092
non-Hispanic white	240	1.93	0.18	2.01	1,107
non-Hispanic black	273	2.55	0.24	1.94	823
Mexican-American	24	3.32	0.60	1.89	NR[f]
Other	92	1.83	0.16	1.94	NR
Midwest Region					
Race/Ethnicity[a]	*n*	GM[b]	GM SE[c]	GSD[d]	PRG[e]
All	945	1.53	0.12	2.18	1,079
non-Hispanic white	428	1.42	0.14	2.11	1,273
non-Hispanic black	347	2.11	0.12	2.24	582
Mexican-American	157	1.88	0.25	2.39	535
Other	13	2.83	0.52	2.07	NR

TABLE 3a. Estimated Geometric Means and Geometric Standard Deviations of Blood Lead Concentration (μg/dL) in U.S. Women, 17 - 45 Years of Age, By Census Region and Race/Ethnicity—*Continued*

South Region					
Race/Ethnicity[a]	*n*	GM[b]	GM SE[c]	GSD[d]	PRG[e]
All	2159	1.39	0.04	2.07	1,366
non-Hispanic white	595	1.30	0.05	2.04	1,485
non-Hispanic black	947	1.51	0.07	2.11	1,211
Mexican-American	560	1.82	0.16	2.16	910
Other	57	1.76	0.20	1.85	NR
West Region					
Race/Ethnicity[a]	*n*	GM[b]	GM SE[c]	GSD[d]	PRG[e]
All	1283	1.40	0.09	2.11	1,287
non-Hispanic white	266	1.30	0.08	2.08	1,410
non-Hispanic black	125	1.87	0.13	2.04	1,089
Mexican-American	821	1.59	0.05	2.31	842
Other	71	1.48	0.20	1.92	NR

[a]Race-Ethnicity categories provided in NHANES III
[b]GM: Estimates of the geometric mean PbB estimated using SUDAAN software.
[c]GM SE: Standard error of the geometric mean estimated with SUDAAN (Taylor series method).
[d]GSD: geometric standard deviation estimated using SASand the WTPFEX6 sample weight.
[e]PRG: Preliminary Remediation Goal; determined with the EPA Adult Lead Model using the indicated GMs and GSDs and with the other ALM parameters set to default values.
[f]NR: Not Reported; PRGs are not reported when the number of observations (*n*) is less than 100.

TABLE 3b. Estimated Geometric Means and Geometric Standard Deviations of Blood Lead Concentration (μg/dL) in U.S. Women, By Age and Race/Ethnicity

Age Group: 17-25				
Race/Ethnicity[a]	*n*	GM[b]	GM SE[c]	GSD[d]
All	1625	1.23	0.05	2.08
non-Hispanic white	417	1.12	0.06	2.02
non-Hispanic black	547	1.50	0.07	2.07
Mexican-American	577	1.55	0.08	2.35
Other	84	1.39	0.14	2.00
Age Group: 26-35				
Race/Ethnicity[a]	*n*	GM[b]	GM SE[c]	GSD[d]
All	1789	1.55	0.06	2.07
non-Hispanic white	568	1.47	0.07	2.05
non-Hispanic black	599	1.72	0.08	2.23
Mexican-American	555	1.74	0.08	2.27
Other	67	1.85	0.16	1.78
Age Group: 36-45				
Race/Ethnicity[a]	*n*	GM[b]	GM SE[c]	GSD[d]
All	1602	1.80	0.07	2.09
non-Hispanic white	544	1.71	0.07	2.09
non-Hispanic black	546	2.20	0.11	2.06
Mexican-American	430	1.86	0.09	2.21
Other	82	2.01	0.19	2.00

[a]Race-Ethnicity categories provided in NHANES III
[b]GM: Estimates of the geometric mean PbB estimated using SUDAAN software.
[c]GM SE: Standard error of the geometric mean estimated with SUDAAN (Taylor series method).
[d]GSD: geometric standard deviation estimated using SAS and the WTPFEX6 sample weight.

TABLE 3c. Estimated Geometric Means and Geometric Standard Deviations of Blood Lead Concentration (μg/dL) in U.S. Women, By Age and Census Region

Census Region[a]	*n*	GM[b]	GM SE[c]	GSD[d]
Age Group: 17-25				
All	1625	1.23	0.05	2.08
Northeast	211	1.67	0.15	2.01
Midwest	267	1.10	0.11	2.00
South	727	1.16	0.05	2.05
West	420	1.07	0.08	2.09
Age Group: 26-35				
All	1789	1.55	0.06	2.07
Northeast	214	2.00	0.26	1.94
Midwest	370	1.54	0.10	2.19
South	744	1.40	0.04	2.05
West	461	1.44	0.11	1.98
Age Group: 36-45				
All	1602	1.80	0.07	2.09
Northeast	204	2.30	0.14	1.99
Midwest	308	1.89	0.19	2.12
South	688	1.62	0.06	2.02
West	402	1.63	0.14	2.16

[a]Census regions provided in NHANES III
[b]GM: Estimates of the geometric mean PbB estimated using SUDAAN software.
[c]GM SE: Standard error of the geometric mean estimated with SUDAAN (Taylor series method).
[d]GSD: geometric standard deviation estimated using SAS and the WTPFEX6 sample weight.

TABLE 4. Comparison of the Rate of Non-Detects in Blood Lead Concentrations Between Phases 1 and 2 of the NHANES III for U.S. Women, 17 - 45 Years of Age

Ethnicity[a]	Phases 1 and 2			Phase 2			Phase 1		
	n	non-detects	% of sample	*n*	non-detects	% of sample	*n*	non-detects	% of sample
All	5016	1070	21.3	2769	681	24.6	2247	389	17.3
non-Hispanic white	1529	434	28.4	788	259	32.9	741	175	23.6
non-Hispanic black	1692	285	16.8	1035	202	19.5	657	83	12.6
Mexican-American	1562	312	20.0	800	191	23.9	762	121	15.9
Other	233	39	16.7	146	29	19.9	87	10	11.5

TABLE 5. Comparison of Blood Lead Concentration Estimates of U.S. Women, 17–45 Years of Age, with Default Values Used in the EPA Adult Lead Methodology						
Ethnicity[a]	NHANES Phases 1 and 2			NHANES Phase 1 (U.S. EPA, 1996)		
	n	GM	GSD	*n*	GM	GSD
All	5016	1.5 (1.4–1.6)	2.1	2250	1.8	1.9
non-Hispanic white	1529	1.4 (1.3–1.6)	2.1	742	1.7	1.9
non-Hispanic black	1692	1.8 (1.7–1.9)	2.2	658	2.1	2.0
Mexican-American	1562	1.7 (1.6–1.8)	2.3	763	2.0	2.1
U.S. EPA ALM (1996)						
	–	1.7–2.2	1.8–2.1	–	1.7–2.2	1.8–2.1

TABLE 6. Comparison of PRGs Calculated with the EPA ALM Using Default Value Ranges or Updated Ranges for the $PbB_{adult,0}$ and $GSD_{i,adult}$ Parameters

	$PbB_{adult,0}$ (default)[a]			$PbB_{adult,0}$ (GM range)[b]			$PbB_{adult,0}$ (95% UCL range)[c]	
$GSD_{i,adult}$	1.7	2.2	$GSD_{i,adult}$	1.4	1.8	$GSD_{i,adult}$	1.6	1.9
1.8	1754	1406	1.9	1712	1434	1.9	1573	1365
2.1	1096	749	2.3	988	710	2.3	849	641

[a]EPA ALM (U.S. EPA, 1996)
[b]Race/ethnicity range of the GM PbBs
[c]Race ethnicity range of the 95% upper confidence limit on the GM PbBs

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